Biobased composites for dental applications: The first steps towards in situ guided tissue regeneration membrane manufacturing

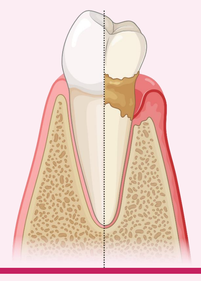
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Introduction

Periodontitis

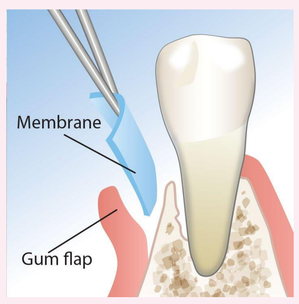
- ➔ Inflammatory disease
- ➔ Degradation of gum and alveolar bone
- ➔ Can lead to tooth loss[1]



Guided Tissue Regeneration (GTR)

- ➔ The most common periodontitis regeneration method
- ➔ Main aspect: **barrier membrane**

Inhibit epithelial cell growth — Promote bone regeneration[1]



Challenges:
- ➔ Outcomes highly depended on surgical precisions
- ➔ No single material can fulfil all functional requirements

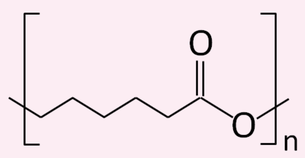
Project Aim

- ➔ To enable **direct application** of GTR materials into periodontal defects by utilising handheld electrospinning of PCL/sodium alginate core-shell fibres, simplifying the procedure and enhancing regenerative outcomes

Study objectives

- ➔ Assess the viability of handheld electrospinning for in situ GTR material fabrication
- ➔ Study the morphological and mechanical impacts of transitioning from a typical desktop to handheld electrospinning

Materials & Methods



20% Polycaprolactone

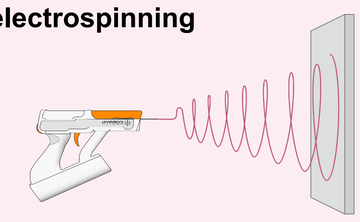
3:7 Acetone/ Acetic Acid



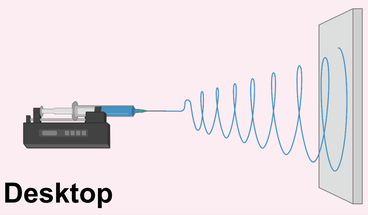
Tip-to-collector distance: 20cm
Flow rate: 3mL/h

Electrospinning

Handheld electrospinning

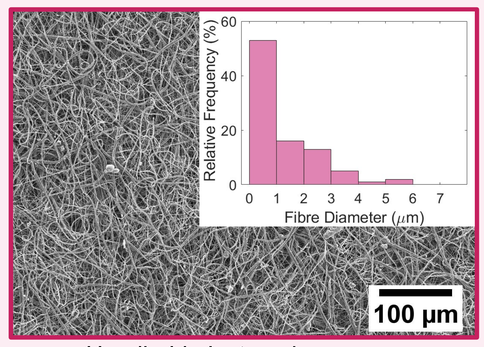


Desktop electrospinning

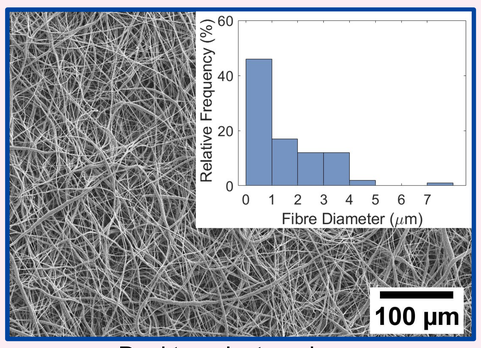


*Aqueous sodium alginate electrospinning was also attempted, but required voltages >20kV, exceeding the handheld limit.

➔Maximum voltage: 15kV
➔Solution is electrified in the syringe via a plunger used to eject the liquid



Handheld electrospinner



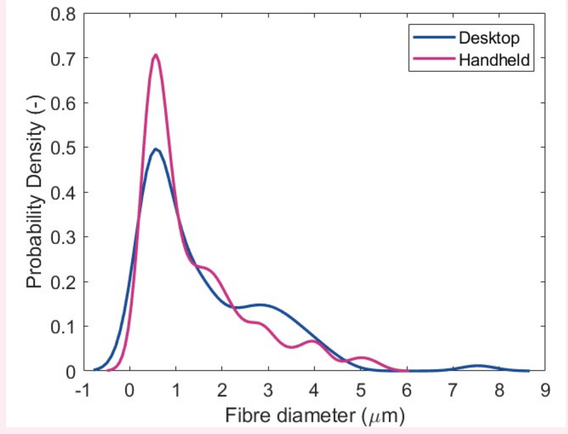
Desktop electrospinner

➔Maximum voltage: 25kV
➔Solution is electrified indirectly through the needle tip, just before ejection

Results

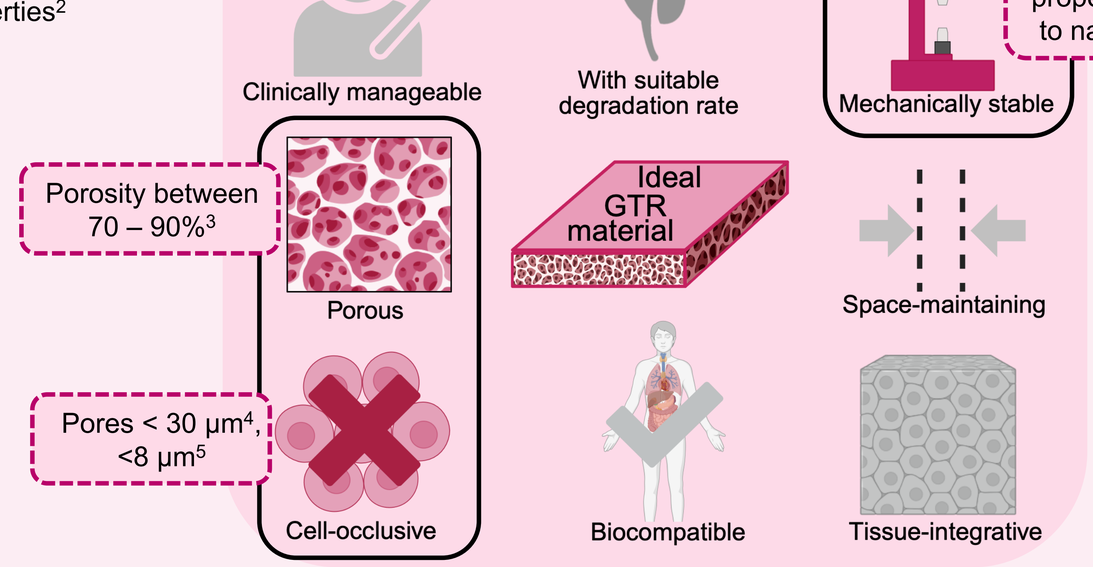
Fibre diameter

- ➔ Pore size depends on fibre diameter
- ➔ Higher aspect ratio provides more surface area for cell attachment and increased tensile properties[2]



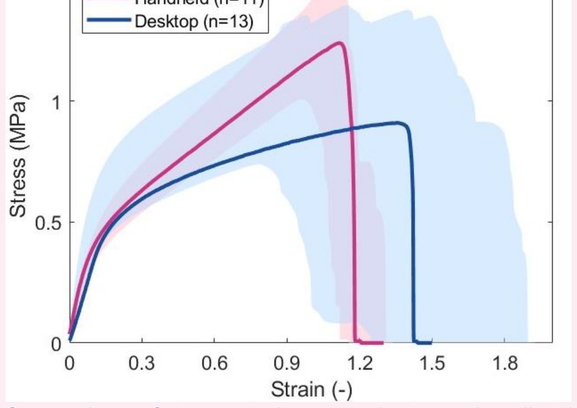
Comparison of fibre size distribution between handheld and desktop electrospinners

Handheld membrane: 1.39 ± 1.15 μm
Desktop membrane: 1.56 ± 1.33 μm



Properties of an ideal Guided Tissue Regeneration material

Tensile Properties



Comparison of stress-strain curves between handheld and desktop electrospinners

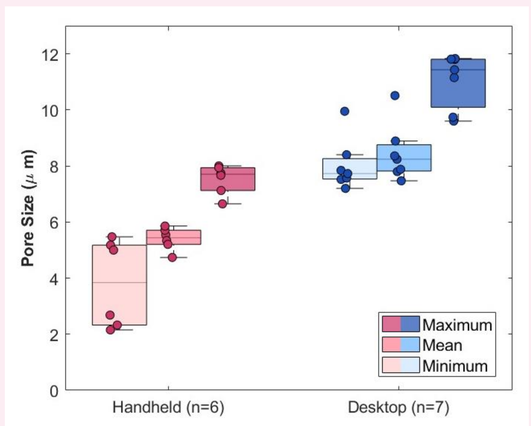
	Handheld Electrospinner	Desktop Electrospinner	Gingiva[3]
Tensile Strength (MPa)	1.28 ± 0.2	1.17 ± 0.33	3.81
Young's Modulus (MPa)	4.95 ± 1.05	7.55 ± 3.13	3-37

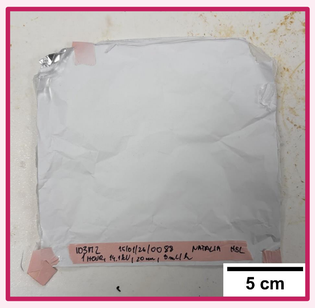
Porosity

Minimum, mean, maximum pore size and a total pore to solid surface area was measured.

	Handheld Electrospinner	Desktop Electrospinner
Min (μm)	3.8 ± 1.4	8.0 ± 0.9
Mean (μm)	5.4 ± 0.4	8.5 ± 0.9
Max (μm)	7.5 ± 0.5	11.0 ± 0.9
% total pore area	29 ± 3	30 ± 2

Comparison of pore size distribution and total porosity between handheld and desktop electrospinners





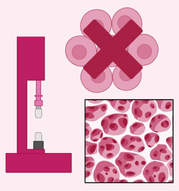
Membrane manufactured with the handheld electrospinner

Main Findings

- ➔ **Fibre diameters** from the handheld device were comparable to the desktop setup, remaining within the micrometre range suitable for cell attachment.
- ➔ **Pore sizes** achieved with both devices aligned with the target cell-occlusive range.
- ➔ **Total pore area** was significantly lower than the ideal threshold for cell growth and nutrient perforation, confirming the need for a multi-layer membrane.
- ➔ **Tensile properties** of the two manufactured materials were comparable. While Young's modulus corresponded to the gingival range, tensile strength requires further reinforcement to match native tissue.

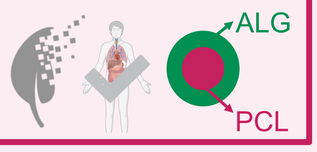
Conclusion

This study demonstrates that handheld electrospinning can effectively replicate the morphological and mechanical properties of desktop-manufactured GTR materials, offering a simplified clinical workflow, while highlighting the necessity of multi-layered architecture to overcome the functional limitations of single-material membranes.



Future Work

Current study: material biocompatibility, degradation profiles
Next steps: PCL/sodium alginate core-shell architectures and multilayered designs



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Figures: https://mycdmr.com/services/guided-tissue.html, https://commons.wikimedia.org/wiki/File:Polycaprolactone_structure.png, created in https://BioRender.com